AN INVESTIGATION INTO THE DISEASES CAUSED BY COAL DUST AND BY THE GASES GENERATED IN THE WORKING OF COAL MINES,

being

A Thesis for the Degree of M.D.
of the University of Edinburgh.

By

ROBERT ESMOND MOYES,
M.B., Ch.B.

April 1910.

S Y L L A B U S.

1. Oxygen.

(a) Diminution of, due to

Use of explosives.
Physiological usage.
Absorption by various gaseous elements.

(b) Quantity generally present in Mines.

(c) Minimum quantity necessary for good health.

(d) Symptoms which appear when quantity of Oxygen below that minimum.
Special Case.

2. Carbon di-Oxide.

(a) Comparison of conditions upon and beneath the earth's surface controlling it.

(b) Causes of increased CO_2 in Mines.

(c) Behaviour of the human organism in an atmosphere of CO_2.

3. Carbon Monoxide.

(a) Sources.

(b) Experiences at a Mine fire.

(c) Dangers associated with its invisibility.

(d) CO in "after-damp".

(e) Use of mice as an indication of the presence of CO.

4. Sulphuretted Hydrogen.

(a) Sources and conditions.

(b) Symptoms of H_2S poisoning.

5. Methane.

(a) Sources.

(b) When explosive.

(c) Fire-damp.

6. Solid Impurities in Mine air.

(a) Coal dust.

(b) Silicon (as Silica Oxide or Silicates).

(c) Other mineral matter.

(d) Bacterial organisms.

7. Fibroid Phthisis.

(a) Causes.

(b) Experimental evidence that an anthracotic condition is adverse to Tubercular invasion.

(c) Sterility of coal dust proved by Bacteriological examination and by the behaviour of wounds.

(d) Channels by which coal dust finds its way into the lung substance.

(e) Pathological appearances of an anthracotic lung.

(f) Greater frequency in the affection of the apices.

(g) Symptoms and course of a case of Anthracosis.

(h) Differential diagnosis between Tubercular Phthisis and Fibroid Phthisis. Use of vaccines.

(i) Treatment of Fibroid Phthisis.

(1) Preventive.
(2) Palliative.

8. Explosives in Coal Mines.

(a) Kinds used and their gaseous products.

(b) Gunpowder.
(1) Analysis of Mine air after its use.
(2) Abuse of the use of Gunpowder.
(3) Symptoms.

(c) Roburite, Tonite and Lydite.
(1) Symptoms.
(2) Report of Special Committee (Durham).
(3) Special symptom of fear attached to use of high explosives.

9. Temperature and Health in Coal Mines.

(a) Factors causing rise of temperature.

(b) Effect of high temperature on Miner when at work.

10. Humidity and Health in Coal Mines.

11. Special illustrative cases.

AN INVESTIGATION INTO THE DISEASES CAUSED BY COAL DUST AND BY THE GASES GENERATED IN THE WORKING OF COAL MINES.

The work of a coal miner is at all times dangerous. The danger of accident the careful workman can often avoid, especially so if he acts in accordance with the stringent regulations laid down by the Home Office which are made for his protection and which are modified from time to time by the many Inspectors of Mines throughout the country. He is, however, greatly at the mercy of the subtle dangers hidden in the atmosphere which surrounds him, caused by the formation of noxious gases and the inevitable coal dust which is a product and constant accompaniment of his work.

Physical injury, both by accident and disease, grow in frequency day by day as the old system of hand hewing is being superseded by the use of explosives.

The reason for the more frequent use of explosives lies in the fact that wages have considerably decreased in recent years, so that in order to make an adequate wage the miner calls to his assistance

a force far greater than he himself can exert to break down the hard seams of coal. The explosives most frequently used are Roburite, Tonite, Melenite, Dynamite, Nitroglycerine and gunpowder, and of these Roburite and Gunpowder are the most common - a high and a low explosive respectively.

The first obvious effect of the use of any explosive is the diminution in the supply of available oxygen, and this supply is further diminished by the large quantity consumed by the miner himself and his many co-workers, in exchange for which a large quantity of carbon dioxide is exhaled.

Although adequate arrangements have been made for the provision of fresh atmospheric air in mines, even at its best it is much poorer in oxygen than the outside air, varying in amount to a difference of several per cent.

The amount of oxygen in the air of mines has been calculated by various observers. Moyle found in the Cornish Mines 17.5%; Brockman, in the Mines of the Hartz Mountains, many of which are situated at an altitude of 3000 feet, found 19.7%, but here the atmospheric pressure possibly plays a part which he did not take fully into consideration. The most important recent investigation was made by Nasmyth in some of the Scottish Coal Mines, where he found

about 20.4% in Mines over 100 fathoms in depth. In the Mines in which my own investigations have been undertaken the percentage, although varying on occasions, works out at an average over the whole year of 19.2%.

Comparing these quantities with the oxygen present in the atmospheric air, the difference cannot be considered greatly out of the way.

It appears to have been a policy with the Management of some mines how <u>little</u> pure air they could give their employees, and this has brought forward the enquiry as to what amount of Oxygen must be present to obviate injury to health. Investigations have shown that 12% is about the lowest margin consonant with safety, for when below that figure, say 10%, the lips become bluish, and if the amount be further reduced to 6% there is violent palpitation, loss of consciousness and rapid death.

In a recent Pit fire which I investigated (viz. Newburgh Colliery, Acklington) it was a common thing for the men who were working to extinguish the fire to become suddenly overcome and exhibit such symptoms as I have tabled above. The major part of the available oxygen was taken up by combustion in the fire, and there remained a very small amount for the workers to come and go on.

Although the symptoms were alarming to a degree, it was remarkable how quickly the men who so suffered became themselves again when placed in an atmosphere of pure oxygen administered from cylinders kept specially for that purpose. In these cases the permanent ill effects were very few indeed.

The effect of pressure plays an important part in those existing in atmospheres where oxygen is diminished in quantity, a diminution in the oxygen of the atmosphere being more easily borne at a great depth than at the surface.

While there is a diminution in the quantity of oxygen in the air of coal mines, there is a corresponding increase in the quantity of carbonic acid. This is easily conceived when a comparison is made between the conditions existing on the earth's surface and those within its interior. In the former there is abundant vegetable life which assimilates large quantities of the carbonic acid, but in the latter the only trace of vegetable life at all is found in the many beautiful fossils, relics of active plant life of bygone ages. Thus there is production of carbon di-oxide without commensurate consumption, and the quantity produced is so great in proportion to that of the air passing through the workings that the percentage of carbonic acid in the return air is

often ten times as much as the amount of carbonic acid found in the air entering the mine for purposes of ventilation.

This increase in the quantity of carbonic acid in coal mines is due to four distinct causes:-

1. Exhalation from the lungs of the miners and horses.
2. Combustion in the oil lamps which the miners use.
3. That given off by the coal itself, the pores of which contain fair quantities of it.
4. That given off by explosives.

It is obviously impossible to attach definite figures for the quantities supplied by each of the above, as they are all so intimately connected with one another, but excepting the question of explosives, which will be dealt with later, there is no doubt that the greater quantity is given off by the coal itself. In this connection the oxidation of the coal as it comes in contact with the atmospheric air adds its quota to the carbonic acid already present. Other additional contributors to the carbonic acid present are the rotting of timbers which are extensively used for holding up the roof of the various "ways" whereby the men have to reach the scenes of their labours, and for the prevention of

coal and stone falling on them when at their work. The density of the carbonic acid being greater than that of air, it naturally falls to the ground, where it lies in a layer in thickness commensurate with the quantity present. This is well exemplified by an experience which I constantly met with when making my investigations underground. In some of the smaller workings where the height in many places did not exceed two feet six inches, and which necessitated walking in a crouching position, the light which I carried continually went out. Miners who accompanied me told me to hold by lamp higher. This I did, and had no difficulty in keeping it alight. The cause of this I found out to be a layer of carbonic acid about eleven inches in thickness on the floor surface. The point to be noticed in this is that the men in these workings are constantly labouring in this stratum of carbonic acid lying on their sides or backs, and thus they are obliged to inhale the gas in which the candle refused to burn. They were practically human candles, the only difference being that in their case they possessed an organism capable of resisting the influence of the gas, whereas the candle had not this.

From my observations I am of the belief that it is quite possible for a miner to become acclimatised

to the inhalation of quantities of carbonic acid, the only point of note being that when placed in these workings for the first time they suffer markedly from disorganisation of the respiratory mechanism, whereas later on these symptoms pass away to give place to more permanent damage in other organs. In such cases the lungs chiefly suffer, emphysema is a marked condition, whilst asthma, of a very bad type, often singles out those who would appear to be the most robust. When a higher percentage than 3 or 4 of carbonic acid is present, the earliest toxic symptoms become manifest.

Other gaseous impurities in the air of mines are Carbonic Oxide, Nitric Oxide, Sulphuretted Hydrogen, Methane, and in some instances traces of Sulphur dioxide and Arsenious Acid can be detected.

Carbonic Oxide.

The sources of this gas in Coal Mines are

1. Through a simple heating of the coal.
2. From underground fires in old workings.
3. By the incomplete combustion of explosives.
4. As the result of explosions which produce "after-damp" - a gas containing varying quantities of carbon monoxide.

Possibly this gas is the most subtle of all gaseous poisons, mainly because, being a narcotic, the nervous system becomes slowly lulled into a happy sleep which ends in coma. On the other hand, in cases of carbonic acid poisoning, as I have already shown, there is usually greater disturbance of respiration. A most striking example of the rapid accumulation of carbonic oxide which may take place through the agency of an underground fire recently came to my notice when I was called upon to treat professionally some men who had been engaged in endeavouring to quench such a fire in Newburgh Colliery. This fire was without doubt a product of spontaneous combustion and had taken a firm hold of one part of the pit. The means adopted to extinguish this fire which was a red hot mass nearly a square acre in area, was to build a wall on every side of it and thus cut off the entire supply of oxygen to that part of the Mine. All went on satisfactorily until the wall was within a few days of being completed. The workmen then found that they were unable to continue their work for more than three or four minutes without suffering from extreme drowsiness. On examination it was found that abnormal quantities of carbonic oxide were finding their way from the site of the fire through the

aperture in the wall which had yet to be completed. The work, eventually, had to be completed by workmen who carried sufficient compressed oxygen with them to last them during the time they were working.

Another source of carbonic oxide is the careless use of explosives in mines. This is especially observable where dynamite is still used as the explosive. Fortunately as the higher and more powerful explosives have been brought into use, dynamite has become more and more abandoned. The products of an incomplete explosion of dynamite are carbonic oxide and nitric oxide, whereas had the complete explosion taken place the gases generated would have been carbon dioxide and nitrogen. The nitric oxide combines with the oxygen of the air and forms nitrous oxide.

A fair amount of carbonic oxide is produced in the ordinary way by the explosion of gunpowder, tonite and roburite, the danger lying where the two latter explosives are used on account of the invisibility of the gases produced, thus tempting the miner to recommence his work before the gases are completely dispersed, whereas where gunpowder is used the carbonic oxide freely mixing with the sulphuretted hydrogen produced side by side in great bulk, is in itself a warning to the miner that the place in which

he is working is still in an unfit atmospheric condition for his return.

Of the three explosives before mentioned, tonite produces most carbonic oxide, gunpowder comes next, and roburite last.

Haldane in his book (The Investigation of Mine Air) has referred to the fact that whilst a large number of miners in colliery explosions lose their lives by the force of the explosions, there is a large mortality recorded amongst those who escape the actual effect of the explosion owing to their inhaling large quantities of the "after-damp". That this is proved to contain large quantities of carbonic oxide is frequently evidenced by the deaths in rescue parties who descend into the pit after an explosion and who are rapidly overcome with the general symptoms of carbonic oxide poisoning, namely, sleepiness, extreme muscular relaxation, and finally unconsciousness.

The pathogenicity of carbonic oxide to mice Haldane has suggested might be turned into good account in such cases. He suggests that mice should be lowered into the pit and that, if they are brought up alive, it is possible for a human being to inhale the atmosphere without being overcome. Later day methods employed by rescue parties consist of the

wearing of a protective helmet which is supplied with a constant stream of oxygen and compressed air from a portable cylinder which each man carries. As it is possible for a miner suffering from carbonic oxide poisoning obtained through inhaling after-damp to live for an hour, it is extremely necessary that this apparatus should be in momentary readiness so that an effort may be made to reach and bring out these men before they die. In the workings near the fire already referred to, the Colliery Management gave me a free hand in making such arrangements so that men overcome by the gas whilst working in its immediate neighbourhood could have prompt attention.

The saving of life from carbon monoxide poisoning in mines by above methods is well illustrated by the decreasing number of deaths notified to the Registrar General and published in his Annual Reports, the latest of which (1908) gives two deaths from this cause in coal mines, and one in other mines, making a total of three altogether.

Sulphuretted Hydrogen.

This gas, which is found in all mines and possibly in copper mines more than others, is caused by

1. Natural chemical causes, such as the decomposition of sulphides.

This is effected by the action of acid or peaty waters on the sulphides, or by bacteria acting as reducing agents on organic matter.

2. Spontaneous heating of coal, which occurs chiefly in coal of a light texture and easily friable. This form of coal exceeds the more dense forms of coal in temperature by from three to eight degrees, and apparently has the property not only of generating but of conserving enormous quantities of heat, which eventually reveals itself in the form of fire. Previous to the outbreak large volumes of sulphuretted hydrogen find their way out into the mine workings.

3. Blasting by gunpowder. This has already been referred to and is a natural product of the explosive when fired. It occurs in small quantities, as a rule, but in much larger quantities when the explosion is incomplete.

In the Mines under my own observation sulphuretted hydrogen was very rarely present in a natural form but appeared in large quantities after the firing of the shots, and was found as late as two hours after work had ceased. The variability of the quantity actually present was exceedingly interesting, as in those workings where there was an accumulation of water the amount present totalled less than 50% of the quantity present in the air of dry workings. This was doubtless due to the extreme solubility of

sulphuretted hydrogen in water which is equally as readily given off if the surface of the water be disturbed.

For many years there have been no registered deaths as having been due to the poisonous influence of sulphuretted hydrogen. At the same time my investigations have amply proved to me that if the quantity existing in the mines under observation was not sufficient to kill, its power as a poisonous irritant was over and over again made manifest.

The symptoms I classify as:-

(a) Mild
(b) Severe
(c) Fatal.

(a) The minor symptoms, which are very mild in form, but which many miners consult a medical man for, are sickness, headache, faintness and often diarrhoea. Needless to say such symptoms yield readily to treatment, and possibly the fresh atmospheric air is as great a medicament as any prescribed physic.

Besides these there are more local symptoms caused by direct irritation, prominent amongst which are the effects of the gas upon the conjunctivae. Miners constantly complain when working in a sulphurous atmosphere of a burning irritation in the eyes. Exemption from work for a few days, and a lotion of

Boracic acid, soon disperse the condition, but if, on the other hand, a person so affected neglects the primary irritation, it speedily becomes transformed into a chronic conjunctivitis, and eventually the eyelashes become loosened and fall away, reappearing, however, when the condition is cured. Another site of local irritation is the air passages, causing at first a mild catarrh but under constant inhalation a chronic bronchitis.

(b) The more severe symptoms do not permit of much warning. Certainly those mentioned above are present, but they are more pronounced and follow each other with greater rapidity, so that within an hour a miner who has inhaled a concentrated gaseous combination of Sulphur and Hydrogen may find himself vomiting heavily, often with haematemesis. He has staggering gait and falls down in the course of a few moments, without even a warning cry.

(c) The fatal cases occur with such crushing suddenness that no premonitory symptoms are available. As such cases are rarely if ever encountered in coal mines, little need here be said beyond the fact that the Sulphuretted Hydrogen has its odour often masked so that a man entering into an area where it exists is unconscious of its presence, and thus being immediately overcome, can give no sign to

others who may follow for the purpose of rescue. Such an accident has not uncommonly occurred in sewers where ventilation has become inefficient.

It has been frequently stated that a human being can live in an atmosphere containing from 1 to 4% of sulphuretted hydrogen, but this is far from correct. Such a percentage means instant death. Lehmann, after carefully investigating the precise cause of death in sulphuretted hydrogen poisoning, gave facts to prove that so small a quantity as .07% can cause death, and that it possibly does so by irritation of the terminals of the pneumogastric nerves in the lungs, but other writers, whilst sharing this opinion, believe that the gas has a direct action upon the respiratory centre.

Of the remaining gaseous impurities, Methane, called under different conditions marsh gas, or mine gas, and vulgarly known to the miner as "gas", need only be considered here. Formed by the decomposition of organic matter in the absence of air, it is found in coal seams in large quantities. This is due to the undecomposed primeval organic matter having been carried down and become hermetically sealed by the earth's crust. During the centuries which have followed, decomposition has proceeded slowly

yet surely until every crevice and the spaces between the seams of coal have become charged with it under great pressure. It thus often happens that it bursts forth, causing a noise like an explosion, and buries beneath the debris which is blown forth with it any workers who may be in the immediate vicinity. In itself it is combustible, burning with a slightly bluish flame, but it is not explosive unless in conjunction with Oxygen. This combination is commonly known as "fire-damp". The presence of Oxygen causes Methane to be breathed without bodily harm ensuing, the danger appearing when a naked light is introduced upon the scene. A violent explosion then follows and the residual gas burns as a bluish-green flame until consumed, the flames following the direction of the outlet shaft.

Solid Impurities.

The most common of these are Coal dust, Silica and Silicates (minute particles of sand, slate, shale etc.). Besides these there are found in nearly every mine particles of sundry mineral matters and chemical compounds, such as the Sulphate and Nitrate of Potassium. Micro-organisms are a variable quantity.

Coal dust owes its presence to the working of the coal whether by blasting or by pick and shovel. A large quantity of this must necessarily be inhaled at the time of its formation, but it may be appreciably lessened by sufficient watering, and its harmful effects diminished by deferring return to "the face" until several minutes have elapsed after the firing of the shot.

Silicon is present in mine air chiefly in the form of Silica oxide (S_1O_2). The latter is widely distributed in nature as a constituent of rock. Quartz and amethyst are examples of a crystalline variety, and flint consists of silica in a more or less amorphous form.

The dust from coal itself seems relatively harmless when compared with the minute particles of what the miners call "stone dust", which may be either quartz, silicon or sandstone. More especially has this been in evidence since mechanical disintegration has become common. For this purpose "coal-cutters" driven by electricity are employed to cut out bands of hard stone which run through the seams of coal. Whilst this makes the task of the coal-hewer less arduous, it opens up a fresh means for the inhalation of minute stone particles, even more minute than those caused by ordinary blasting, as the rock is ground up

into a veritable powder. So powerful are the effects thus produced that men under my own observation have been unable to continue at this work for more than nine months at a time, and this despite the inducement of the high wage offered. Indeed, many give up before this time has elapsed, and not a few have shown signs of fibroid phthisis. Their cases will be referred to later.

Nevertheless, it is a remarkable but well established fact that phthisis amongst coal miners is a disease of much greater rarity than has been suggested by many writers. Certain symptoms common to phthisis and simple fibrosis of the lung have been responsible for this error, but recent investigations based on Koch's law that the Tubercle bacillus must not only be found but cultivated, and when inoculated into another animal produce similar symptoms, has caused to be eliminated many cases which otherwise would have been regarded as phthisis, no tubercular organism having been found.

According to a census taken amongst mine workers in the United States, Pulmonary Consumption caused but 10.6% of the total deaths, as against 16.2% for all occupied males. This points to the fact that this disease is nearly one third less amongst miners than all other males which have occupations. (See

Tatham in "Dangerous Trades", page 157.)

Dr John Tatham has shown similarly that in Great Britain there is very little deviation from these figures. In this country there are approximately 882,345 coal miners, of which 709,339 work under ground. Between the ages of 15 and 25 years, as well as above 55, miners die in the aggregate more rapidly than occupied males, although the phthisis death rate is lower. A large proportion of deaths amongst coal miners is from accident rather than from disease. In the case of the younger worker he has not been in the mine a sufficient length of time to realise the dangers with which he is surrounded, while on the other hand the older miner, although endowed with experience, is getting up in years and his senses being less acute than they were, he is less able to guard himself against the dangers which he so well knows are near to him.

Drs T. W. Wainwright and H. I. Nichols found that at Scranton, a mining centre in the United States with a population of 100,000, tuberculosis was about two-thirds less frequent amongst miners than amongst all occupied males.

The comparative rarity of Tuberculosis amongst miners is also remarked by De Croeg in the case of

Belgian miners, and by Arnold in the case of German miners. In both these countries there is a prevailing opinion that not only anthracosis but that pneumoconiosis generally is antagonistic to tuberculosis, the latest theories being that the fibrosis caused by the mechanical irritation of dust particles should be an additional barrier against the invasion of the tubercle bacillus which is proved to have no great affinity for fibrous tissue.

The diminishing number of cases of true pulmonary phthisis amongst mine workers cannot be said to be solely due to the improved methods of clinical investigation before referred to. Quite as great a factor is the improved method of living which is aimed at by the local authorities in power in the mining districts. Better housing and prevention of overcrowding lead in these reforms. The terribly overcrowded conditions to which miners have been subjected in their domestic life must have been the gateway whereby the tubercle bacillus has found its way into a lung already impaired by fibrosis, thus curtailing the circulation and enfeebling that organ in its battle against the invader. It is not even now uncommon to find small one-roomed cottages with no through ventilation inhabited by five or six of a family. I have, in conjunction with the Medical

Officers of Health of this district, looked into the conditions of living amongst miners, and I have been shocked to find not only overcrowding, as already referred to, but an insanitary condition so gross as to make one wonder why pulmonary phthisis occurs so infrequently.

It is therefore to the improvement in the social conditions of the worker rather than to any difference in the working conditions in the mine that credit for a diminution in the number of cases of phthisis must be given, for the coal dust is just as prevalent in the mines at the present time as it was in former years. The coal miner is not a picked worker. He is a miner because his father was one before him, and there is extant no process by which the men most suited to the hardest work have it to do, except that of survival of the fittest.

The probability of there being some property in coal dust which is antagonistic to tubercle has received no little attention. The experiments of Wainwright and Nichols seem to show that coal dust has this property. Amongst other experiments they rendered a guinea pig anthracotic by exposing it to coal dust and found that on injecting a pure culture of tubercle bacilli into the windpipe, although the cervical, substernal and mesenteric glands showed

signs of tuberculosis, the lungs, which had been rendered black by the coal dust, were mostly healthy. On the other hand those guinea pigs which were not rendered anthracotic all became the subjects of pulmonary tuberculosis after the injection.

Investigations carried out by myself have unfailingly proved that coal dust is perfectly free from pathogenic organisms. Coal dust placed on various media produced no growth in any case. Even the air in the mine when aspirated through nutrient broth failed to produce any definite growth although the media became carbonaceous. The results of these experiments are fully borne out in practice. That fresh coal dust is sterile is proved by the frequent absence of any pus forming action in wounds due to accidents in which it has had access. In passing, two cases will suffice. The first was a compound fracture of both bones of the leg, treated in a collier's house. The wound could hardly be seen for coal dust, and the protruding bones were covered with it, and the hollow formed by the natural position of the bones was full of it. In this case the bones were replaced and set and the wound healed without any further trouble. The second case was that of a man who had sustained a compound fracture of the humerus just above the elbow joint. The fracture

communicated with the joint and the wound was so full of coal dust that it was impossible to remove it all. The arm was set and the wound stitched, with the exception of the lower end where a drainage tube was inserted. The wound healed by first intention and the man has now perfectly natural movement of his elbow joint.

As to the theories why coal dust should have this sterilising property, several have been propounded, all of them being more or less problematical, that of Nichols finding most favour which asserts that the protective influence is due to the calcium salts which form such a large proportion of the ash of coal dust.

The less irritating effect of coal dust is also to be noticed. This is more apparent when its irritating effects are compared with the dust particles of other hard minerals. This may be in a large measure due to the fact that the minute particles of coal dust which are held in suspension in the air are rounded and soft in character and hence do not cause the same degree of irritation as the sharp jagged particles of stone dust which is so fatal to those who work amongst it.

Whilst gaseous impurities make themselves speedily felt in their effects, coal dust on the other

hand is slow, insidious, but all too sure in the production of its harmful effects, and in the hurry and bustle of life the miner either fails to recognise the early symptoms or proceeds to take no notice of them. The majority of miners who visit one's consulting room come complaining of a cough and ask for a "cough bottle", which is practically the end of the matter so far as they care. This cough goes on year after year increasing in intensity, and the miner is well on the road to a fibrosis, chronic bronchitis and emphysema before he realises that he is in the middle of the stream leading to the whirlpool of premature old age, chronic invalidism and misery.

The action in the case of poisonous gases is one of comparative rapidity, as they gain access to the circulation through the lungs and immediately produce their distressing symptoms. Their action is thus mainly through the medium of the blood stream which carries the messenger of disease to other organs, more especially the blood forming organs, and making them abnormal in action produce those forms of chronic anaemia so frequently found amongst coal miners. The action of the dust, on the other hand, is purely that of a local irritant. It makes its way into the small bronchi and pulmonary alveoli, and setting up a chronic catarrh prepares the tissues for any

invading organisms which may chance to pass by. The dust reaches the lungs much less frequently than it would do were it not for the action of the ciliated epithelium which is engaged in constant effort to expel it. Colds, catarrh and this chronic irritation due to the presence of the coal dust weaken the epithelium, and diminishing its expulsive power deprive the lungs of one of the main sources of their defence. Thus the dust more easily reaches the pulmonary alveoli, and setting up a low form of inflammation ends in the transformation of the spongy substance of the lung into a hard, fibrous, unyielding mass quite unfitted for respiration. The phagocytic cells play a great part in this connection. Particles of coal dust coming into contact with them are devoured by them just as are ordinary organisms, and these cells having mobility pass through the walls of the alveoli and reaching the lymphatics of the lung either deposit the coal dust there or in the surrounding tissue, or in the bronchial glands.

In the same proportion as dust particles penetrate the lung substance, so does the growth of fibrous tissue follow, this going on until in time the lung becomes markedly fibrotic in character. Post-mortem examinations which I have made on miners, even on those whose death had been caused otherwise than

by lung mischief, have brought these points to light. There is on the surface a uniformly black colour, and when an incision is made the gritty particles can be distinctly felt against the knife's edge. Taking a piece of lung tissue between the fingers and pressing it hard, the presence of these gritty particles is distinctly felt. More especially is this so in the region of the apices where such concretions are usually very numerous in men who have worked in the pits for years. These concretions are surrounded by strong fibrous tissue, shewing that the original concretion was the cause of the irritation which finally led to the formation of fibrous tissue on an effort on the part of the lungs to repair themselves. The black appearance of the lung is not, however, wholly due to pigmentation by coal dust. In many cases, and in fact in all cases, it may be seen that a proportion of the pigmentation is due to the staining of the lung tissue by haematoidin. The particles in the more delicate tissues lead to ulceration and thus to bleeding, and in the same way, due to rupture of the capillaries, there is an escape of red blood corpuscles which eventually produce the same effect.

A condition of chronic bronchopneumonia is not uncommonly met with in these cases, and fibrous

tissue forms more rapidly until the lung becomes largely fibrotic in character.

A point of extreme interest is the frequency with which this fibrotic process attacks the apices of the lungs. The reason for this seems to be in a less measure due to the fact that the apex of the lung is less vascular than the anatomical support which is less at these parts than over the remainder of the lung. It has been frequently pointed out as an explanation of the frequency of tubercular disease occurring in the apices that here the lungs are not supported by the ribs in the act of coughing, and hence the expulsive act is less completely carried out.

This fibrotic lung may eventually be attacked by tubercular disease, but the process is one quite distinct from the anthracotic condition caused by the coal dust. That this does not happen more frequently is in my opinion, as I have elsewhere stated, due to the fact that fibrous tissue does not possess any attractions for the tubercle bacillus.

The symptoms commonly found in miners suffering from this fibrotic condition are well illustrated in Cases No.4 and 5 at the back hereof, and are first of all, breathlessness. This appears very gradually and the first indication to the miner himself is that

he becomes easily 'short-winded' when walking up a hill, hurrying, or exerting himself more than usual. It is frequently for this condition that he seeks medical advice. Following this come repeated attacks of bronchitis, mild at first, but gradually becoming more and more severe, and associated with this is a typical "black spit". This on examination is found to contain particles of carbon. In these investigations the possibility has not been lost sight of that the pigmented sputum may be accelerated by heavy smoking, and cases have been examined where the patient has been a non-smoker but the difference has been immaterial. Whilst this bronchitic condition progresses, the fibroid condition is busily at work destroying the circulatory area in the lungs so that marked obstructive symptoms soon make their appearance. Of these the most prominent is swelling of the extremities, finally resulting in general anasarca. All this has been due to dilatation of the right side of the heart, the result of backward pressure. In such cases death results from gradual weakening of the cardiac muscle and consequent incompetency of the cardiac valves. In some cases death overtakes the miner suffering from anthracosis before the last named stage is reached. Owing to a curtailed and imperfectly

oxygenated blood supply his tissues in general become emaciated and he succumbs to general asthenia. Finally, the condition known as fibroid phthisis claims a number of cases. Certainly in a few of these the tubercle bacillus is found, but its presence there is really not due to the occupation of the sufferer but rather to an old tubercular infection possibly acquired from drinking tubercular milk when an infant when one or more mesenteric glands became infected. The depressed tissues having now lost their resisting power, the tubercle bacillus finds an easy prey for its ravages. In the majority of cases, therefore, the tubercle bacillus is not found.

The question naturally arises, can, and if so, how can these two conditions Tubercular phthisis and fibroid phthisis of coal miners be distinguished? Personally I admit to having found difficulty in answering the question, but my notes of many cases have justified me in tabulating the distinguishing points:

Tubercular Phthisis.	Fibroid Phthisis.
1. Family History of Tuberculosis.	Occupation.
2. Cavity formation present.	No true cavity formation but often a bronchiectatic condition.

Tubercular Phthisis.	Fibroid Phthisis.
3. Haemoptysis common.	Haemoptysis mostly absent.
4. Expectoration nummular and yellow.	Mucopurulent, frothy, and bad smelling: colour grey-black.
5. Temperature decided evening rise.	Absent.
6. Hectic fever prominent.	Rare.
7. Larynx, tubercular ulceration: loss of voice and dysphagia.	Catarrhal condition, mechanical irritation only, no loss of voice.
8. Diarrhoea usually profuse, due to swallowing of Tubercle Bacillus.	Absent.
9. Microscopically, Tubercle Bacillus present.	Tubercle Bacillus rarely present, but much carbonaceous matter.

The symptoms before mentioned do not call for any lengthy dissertation, the point being to clearly recognise what is tubercular and what is not. If any doubt exists, the investigator can call to his aid one or another of the diagnostic vaccines recently introduced for the diagnosis of tubercle. Personally I have done so in a few cases, and although

the time which has since elapsed does not warrant any dogmatic statement, I am in my own mind satisfied that Calmette's ophthalmo-reaction is reliable and if used in proficient hands there need be no cause for the prejudice which some investigators have against it.

I make it a rule to carefully examine the condition of the throat, as I am convinced that a painstaking and careful examination will often reveal signs of early tubercle.

Treatment.

The treatment of fibroid phthisis has appealed to me under two headings, viz:

1. Preventive.
2. The adaptation of some form of treatment which will arrest the disease.

1. Amongst preventive measures the essential must necessarily be the prevention of inhalation of the coal particles. To effect this a respirator must be worn. Such may be composed of fine gauze or a chamber containing cotton wool in a loose form. The form of respirator which I have found most efficient is in the shape of a Schimmelbusch's Anaesthetic

mask but made of celluloid. It has the advantage of being light and easily cleaned, the wearer only having to renew the gauze at intervals. It is fastened round the ears and back of the head by an elastic band.

There must be frequent watering of the workings for depositing the dust as quickly as possible, and the workers must be made to allow sufficient time to elapse before returning to the workings after the use of explosives.

To these must be added the abandonment of this occupation when it is proved that the worker is in danger of tubercular or fibroid phthisis.

2. Regarding the treatment of the disease itself, little can be done by the use of drugs. Iodide of Potassium used empirically with the object of absorbing some of the fibrous tissue may be tried, but in my own practice I must confess to being disappointed with the results. The essential outlines of treatment are, firstly, the maintenance of the system in good tone by plentiful supplies of good food and fresh air, always bearing in mind that the lung condition has diminished the oxygenating properties of the blood and that therefore to recompense for this loss one must provide for a greater

supply of oxygen from the air. To these I have made it a sine qua non that the patient shall engage in such exercises as shall contribute to the expansion of the chest wall and thus give the lungs an opportunity to reassert themselves, besides which I am of the opinion that pleuritic and other adhesions are in this way broken down. What these exercises shall embrace must be considered with each individual case, but taking things generally I recommend at first simple breathing exercises with vertically extended arms and gradually bringing the patient to the more laborious exercises of physical culture. That much good is accomplished by treatment on these lines I have had ample evidence in the records of cases now before me.

Explosives and their Effects.

The Explosives Act of 1875 was the turning point in the era of the manufacture of explosives in this country. Although many of the higher explosives had previously been manufactured on the Continent, numerous factories were erected in various parts of Great Britain, some owned by Continental firms, where high explosives were manufactured. This, naturally,

brought the use of higher explosives more into the focus of miners and quarrymen who had previously been ignorant of their uses. The more common ones manufactured and used are Roburite, Tonite, Melenite, Dynamite, Nitroglycerine and Gunpowder. All of these have been used in Mines with the exception of Melenite. Tonite is composed principally of an equal proportion of gun-cotton and barium nitrate, and upon explosion the products formed consist of carbonate of barium, nitrogen, oxygen and water. Roburite is composed of ammonium nitrate and dinitrobenzole in intimate mixture under an atmosphere of chlorine, and produces on explosion hydrochloric acid, nitrogen, carbonic dioxide and water. Gunpowder is composed by a mixture of charcoal, sulphur and saltpetre, and produces large quantities of carbon monoxide and carbon dioxide, together with sulphuretted hydrogen and nitrogen.

The following analyses which I made give an idea of the change wrought in the atmosphere of one small working by the explosion of a gunpowder shot.

Analysis No.1 is that of the air at the 'face' before shot was fired:

Carbon Dioxide	42.6 vols. per 10,000
Carbon Monoxide	Very slight trace.
Sulphuretted Hydrogen	Small quantity.
Nitrogen	Present.

There was also present very minute traces of hydrochloric acid and carbonate of barium.

Analysis No.2, immediately after firing shot:

Carbon Dioxide	52.3 vols. per 10,000
Carbon Monoxide	0.05%
Nitrogen	Present.
Sulphuretted Hydrogen	Large quantity
Hydrochloric Acid	Small quantity and impure
Water	Present.

Analysis No.3. Atmosphere from same place twenty minutes after shot fired.

Carbon Dioxide	48.5 vols. per 10,000
Carbonic Monoxide	About 0.006%
Sulphuretted Hydrogen	Present
Nitrogen	Very slight trace.

By far, the explosive most commonly used in the Northumberland Coal Fields is gunpowder. Its slowness of action is suitable for the purpose for which it is used. It is fired by making a fuse of such a length that the workmen has time to seek shelter before the explosion occurs. Many of the accidents due to explosives have in my experience been caused by the use of too short fuses in the hope of saving time, or, where the miner's light has been in too close contact with the gunpowder. The disadvantages of the use of gunpowder from the standpoint of physical injury consists in the large quantity of smoke

which is given off, which has a pungent sulphurous odour, and the carbon monoxide, which is certainly present in injurious quantities. There being no regulations as to the quantity of gunpowder used, in some places it is employed almost to abuse. This fault lies chiefly at the door of the young coal hewer. The miner who has been at his work for years as a general rule does not use gunpowder to excess, and even when he does use gunpowder he is much more careful to allow the fumes to disperse before he goes in to the 'face' again. It is the young man, being anxious to have as much money as possible for his pay, who rushes back before the atmosphere is cleared and who suffers. This is illustrated well by the case of a father and son who are working in the Broomhill Pits. The father, who has been a coal hewer for over forty years, uses only five pounds of gunpowder per week, whereas his son, who has been a coal hewer for twelve years, uses ten pounds of gunpowder weekly, to which fact there is no doubt his symptoms of illness are attributable. After carefully interrogating many coal miners on the question of the amount of gunpowder used, I find that the average varies from 7 to 14 pounds weekly, and that as a rule the greater bulk of this is used by the younger men.

The symptoms attributable to the use of gunpowder are those referred to under the discussion of carbon dioxide and carbon monoxide. In addition to these I have tabulated the symptoms as narrated to me by the miner who comes for medical help. They are as follows:-

1. Violent frontal headache of a thumping character, the common expression used being "as if something were going to burst in my head".

2. Sickness which may be accompanied by vomiting. In many cases there is no vomiting, which is against rapid recovery, the patient feeling greatly relieved after vomiting has taken place.

3. Severe palpitation of the heart with more or less irregularity of the heart's action.

4. A feeling of dryness in the throat and a rawness beneath the sternum, this symptom leading the miner to call at the Public House on his way home from work.

5. These symptoms may in extreme cases, fortunately rare, pass on to a feeling of drowsiness and even coma. The workmen say that they first lose the power of the limbs and then turn sleepy.

The foregoing symptoms are well illustrated in Cases 1 and 3 appended hereto and must be distinguished from those produced by the higher explosives.

<u>In Roburite</u> there is the same frontal or occipital headache with sickness and perhaps vomiting, but

the distinguishing symptoms are:

1. The numbness of the fingers and toes, these having a prickling sensation like pins and needles.
2. A desire to sleep rapidly follows the above.
3. The urine is the colour of Port wine.
4. Cyanosis of the face and lips.

In addition to these, Ross, who has investigated carefully the effects of Roburite explosions, mentions in the Medical Chronicle, Vol. 1886-7, the following additional symptoms - Loss of sexual desire, hyperaesthesia of the skin, loss of vision, loss of power in the feet so that the person affected was unable to stand, and diminished power in the functions of the flexor tendons, such as in grasping the hand.

The symptoms complained of by the miners in Durham, where Roburite is more extensively used than in Northumberland, are frequent bilious attacks and jaundice. These symptoms were enquired into by a committee consisting of Professor Bedson of the Armstrong College, Newcastle-on-Tyne, Dr Drummond, senior Physician to the Newcastle Royal Infirmary, and Dr Hume. Their observations, which were to decide the question as to the use of Tonite and Roburite being injurious to health, are recorded in the

transactions of the Federated Institute of Mining Engineers, 1881. Their finding was that the symptoms complained of were not so much due to the Roburite and Tonite themselves, although they naturally produced ill effects, as to the fuses used, and they recommended the firing of the fuse by electricity and that no miner should return to the workings until at least five minutes had elapsed from the firing of the shot. This Committee remarked upon the comparative mildness of the symptoms and the facility and rapidity with which they disappeared. They attributed this to the efficient way in which the Durham Mines were ventilated. Ross's investigations took place in the coal mines of Lancashire where the conditions are totally different, and hence the greater number of severe symptoms which he has found to be more or less persistent and permanent.

Amongst my own cases are those of men who have worked with Tonite, Roburite and Lydite, and the prominent symptom which they all possess is one of reduced nerve fortitude and courage. They state that they have a presentiment of coming misfortune, and at night they cannot sleep. One patient, who has called as I pen this, tells me that he is afraid to go to bed lest anything should happen to him. When he does go to bed he is almost sure to be seized with

this dread and has to rise, dress and go for a walk in the fresh air. This case is but an instance of many such and indicates how complete may be the nervous breakdown under the influence of the products of these high explosives.

The treatment for all these conditions must necessarily consist of combating the symptoms. The main point to be aimed at is the achievement of an ideal ventilation which will quickly remove the noxious gaseous elements and leave the worker free to breathe such comparatively pure air as will carry into his lungs the necessary constituents for the nourishment of his body, more especially providing for that clearness of mental perceptivity which is so essential for the preservation of his own life and the lives of his fellow workers.

Temperature.

The temperature of a coal mine is a condition essentially connected with the formation and expansion of the gaseous products previously referred to, besides having a direct influence on the health of the miners themselves. Various factors determine the temperature. It increases with the depth of the mine, approximately 1° F. for every 220 feet.

Other contributory influences on temperature are the number of men working, the use of lights and explosives, the mining operations themselves, and the crowding together in any part of the mine of a large number of workers. As a rule, however, the oxidation of the minerals by air is a much greater factor in heat production than the use of lights or of respiration or of explosives. The temperature of mines was found by Nasmyth to vary very little with the seasons of the year, with which finding I am in perfect agreement, and in addition find that the variability decreases directly as the depth. Between the months of September and January the highest reading obtained by Nasmyth was 55.5° F. and the lowest 53° F., these being taken at the same place.

The effect of a high temperature on the miner when at work results in raising the temperature of his body, and I have found that the temperature of a miner may rise as high as 100.5° without any marked discomfort to himself, but that when this limit is exceeded it caused such discomfort as to incapacitate him from work. The symptoms of which they complained were headache, sickness, rapid pulse and increased respiration, together with profuse perspiration, so that if they persevered they speedily became exhausted. An unusual opportunity of determining

this recently presented itself to me at the Newburgh Colliery where a serious fire has been raging for over six months about 600 feet below the earth's surface. Strenuous efforts were made by the Colliery owners to overcome it and the men were paid liberally so as to induce them to do their best in combating the fire. From careful records which I kept I found that after the body temperature of these workers reached from 100.5° to 100.8° they had to forsake their work and pass into a cooler atmosphere.

Closely related to the question of temperature is that of humidity. All mines are more or less damp, but in some cases the accumulation of water is so great that the miner is lying in water all the time he is at work. The greater the temperature of the mine the greater is the humidity present, unless there is a plentiful current of dry air in circulation. The humidity practically increases with the depth and the relative humidity over the whole year varies between 93% and 100% of saturation.

I have not found lung disease extensively caused by either the temperature or the humidity in the mine. Whatever harm results from these factors takes place when the miner leaves his work to come into the open

air. He generally emerges from the cage covered with perspiration and with his clothing wringing wet due either to the perspiration from his body or to the humidity of the air whence he has come. In this condition he may have to walk a mile, or perhaps two, to reach his home in the early hours of a winter's morning. The result of this is seen in chills of varying degrees of severity, often terminating in pneumonia. When enquiring the precise time when he took ill, a common reply is "I felt it strike me whenever I got to bank in the morning".

Haldane's Investigations in his report on the 'Health of Cornish Miners', 1904, are worthy of notice. He found that so long as the temperature of the mine was not excessive, the percentage saturation of the air with moisture had practically no effect on the comfort or health of the miner. He found that in still and saturated air at a temperature of 80° to 85° it was hardly possible for men to do continuous work even when stripped to the waist. At a temperature above 90° by the wet bulb it was only possible to work for short periods, and Haldane found that it was matter of great difficulty for him to stop in the mine although doing no work, so much so that at a temperature of 93° in still and saturated air, although stripped to the waist, his tempera-

ture rose five degrees in two hours, and was still rising when he came out.

My own investigations carried out in the vicinity of the mine fire already referred to, shew that the miners experienced discomfort in working at a dry heat from 110° to 130°, and that when the temperature exceeded this height those exposed to it had to cease work. In the presence of a moist heat, however, the temperature which the workmen were able to endure was a maximum of 110°, and only then with discomfort. When this temperature was reached the body temperature was generally about 102°.

Although the temperatures returned by my investigations are on a somewhat higher scale than those of other observers, their accuracy has been carefully assured by control experiments.

In concluding this effort to record my personal observations on a fruitful source of disease and disablement, I am conscious of many imperfections which this dissertation possesses. The physical examination of over a thousand miners and the compiling of records connected therewith have involved much labour

and patience; but the subject is one well worthy of any trouble expended upon it when it is considered how many lives of miners in this our country are wrapped up in the elucidation of the diseases to which they stand exposed. And if by reason of circumscribed surroundings one cannot contribute a loaf to this elucidation one lives in the hope that any crumbs of knowledge thus contributed may help in securing better conditions of living and working for those noble men whose toil lies in the darkness but for whom the sunlight of nature and of health was equally created.

A P P E N D I X

Six Clinical Cases

illustrating conditions referred to in the Text,

these being typical examples of many others.

CASE I.

Illustrating effects produced by working in Gunpowder laden atmosphere.

John Burn, Coal-miner, aet 32. Seen Oct. 16th, 1909.

Complaint:

A raw feeling under his breastbone, cough and shortness of breath on exertion. He had had a black spit for two years but this was now yellow. He had been able to follow his employment as a coal-hewer up to the time of his present illness.

Family History:

Good. Parents alive and healthy. Mother aet 62. Father aet 64, and a coal-hewer. Five sisters alive and in good health. Patient has four young children, the oldest being six years. All healthy.

Personal History:

Been a coal-miner from youth, having gone down the pit when aged 13 years. Always been a hard worker. Moderate drinker and smoked an average of two ounces of "thick brown" tobacco per week. He had a good home and lacked none of the necessaries of life.

Previous Illnesses:

Had occasionally lost a few days' work owing to the "powder reek" settling on to his chest. No other illnesses.

Present Illness:

For three years patient had found he was unable to do the amount of work he could do before that time. He was short of breath on exertion and this was most marked when ascending the steps out of the pit or hurrying along on the level. He had had a cough and spit for the last five years. The spit, however, was yellowish in colour at this time. His most distressing symptom was a feeling of rawness which gripped him in the throat and under the breast-bone. This he found was invariably worst after a heavy day's work among powder smoke. It was accompanied by a severe frontal headache and a distressing thumping sensation of his heart. He felt that if he had been able to vomit his symptoms would have been alleviated.

Attributing his symptoms to the fumes resulting from the gunpowder exploding, he had a year previously given up coal-hewing for two months; during this time he enjoyed immunity from these symptoms but only for them to return on his going once more into a gunpowder laden atmosphere. He was in the habit of using about 10 lbs. of gunpowder for shot firing each week.

Physical Examination:

Inspection:

Patient was a man of stout build. Weight 12

stones, stationary. Height 5 feet 10 inches. Temperature normal, pulse 74 and respirations 18 per minute.

Chest somewhat barrel-shaped. Expansion poor. Slight bulging of left apex on coughing. Measurement at line of nipple on expiration 36", inspiration 37".

Palpation:

Expansion of chest moderate, the upper half of the right lung expanding less than the rest of his chest.

Vocal Fremitus slightly diminished except at the bases of the lungs behind where it was normal in intensity.

Percussion:

Right lung: An area of dulness was made out extending from the apex down to the level of the spine of the scapula posteriorly, and as far as the 2nd rib anteriorly. The percussion note over the remainder of the right lung was slightly hyperresonant.

Left lung: There was present an area of slight dulness extending from the apex to the level of the first rib anteriorly and to the upper border of the scapula posteriorly. The percussion note over the remainder of the left lung was somewhat hyperresonant, this being more marked than in the case of the right

lung. The superficial cardiac dulness was obscured.

Auscultation:

Right lung: Over the area of dulness described above the breath sounds were vesicular and faint. The vocal resonance was not marked and there were no accompaniments. The breath sounds over the remainder of the right lung were vesicular with a slight prolongation of expiration. There were one or two medium pitched dry râles to be heard in the infrascapular region.

Left lung: Over the apex of the left lung the breath sounds were harsh and vesicular in character with a slight prolongation of expiration.

Vocal resonance was slightly increased and there were some medium pitched dry râles to be heard.

Over the remainder of the left lung the breath sounds were vesicular and somewhat distant in quality. Vocal resonance was slightly diminished and one or two dry râles were to be heard at the base posteriorly.

The sputum was muco-purulent in character and no tubercle bacilli were found.

Circulatory System:

Palpation:

The apex beat was found in the 5th interspace and normal in position. It was only felt when the

patient bent himself well forward. There was no pulsation in the veins of the neck but a marked epigastric pulsation.

Percussion:

The right side of the heart was somewhat dilated, being defined on deep percussion half an inch to the right of the sternum.

Auscultation:

The sounds of the heart were closed in all areas and somewhat slapping in character.

Pharynx and Larynx:

There was marked pharyngitis present, the tonsils were somewhat enlarged.

On laryngoscopic examination the vocal cords moved equally but were very congested.

Treatment and Subsequent History:

Owing to the advance of the disease at this early age I counselled the man to change his occupation. This he has done, and during five months which have since elapsed the symptoms complained of have entirely disappeared and there has been marked progress in his return to normal health.

CASE II.

Illustrating symptoms produced by working in carbon dioxide.

Thomas Waller, Coal-miner, aet 49 years. Seen 10th Nov., 1909.

Complaint:

Cough, shortness of breath and palpitation.

Family History:

Good. Father dead, aged 50 years. Cause unknown but patient attributes it to his alcoholic habits.

Mother alive, aged 70 years.

Patient has four sons and one daughter alive and healthy.

Personal History:

Patient has been a coal-miner from youth and a coal-hewer for 20 years. He has been a hard worker and a moderate drinker and smoker. He has always had a good home.

Previous illnesses:

None of note.

Present Illness:

Patient had been working for three months in a part of the mine where there was a poor supply of air. He had also been working close to some old workings

and he attributed his symptoms to the "stythe" or carbon-dioxide which found its way through the face to the locality in which he was working. This had been so bad at times that he had much difficulty in getting his candle to burn.

He found that he was very short of breath and suffered much from palpitation of his heart and had a constant desire to cough. These symptoms were at times so distressing that he had to leave his work for a time and seek an atmosphere of greater purity which would give him temporary relief. He had no desire to work and the feeling of palpitation when he endeavoured to persist at his work became such that he could only describe it as a feeling of fullness at his heart which felt as though it would burst. This was accompanied by giddiness, a desire to vomit and a severe headache.

He had no doubt as to the course of his symptoms because on changing places with a fellow-workman he enjoyed immunity from them while his fellow-workman complained just as he had himself done previously.

At this time he was using no gunpowder at all, his work being done entirely while he was using the pick in a lateral posture. He explained that he got a bigger dose in this position as the air was much more impure at a low level than close to the roof.

Physical Examination:

Patient was a man of poor physique. Weight 8 stones, stationary. Height give feet two inches. Temperature normal. Pulse 76 and respirations 18 per minute.

Respiratory System:

Chest Inspection:

Chest markedly barrel-shaped. Measurement, expiration 34½", inspiration 35". Expansion poor. There was bulging of the left apex.

Palpation:

Vocal Fremitus normal.

Percussion:

The percussion note over the apex of the right lung both in front and behind was dull. This area extended as far as the space between the first and second ribs in front and the scapular spine behind. The remainder of the right lung and the whole of the left lung gave a note of marked hyperresonance.

Auscultation:

Over the above mentioned area of dulness, the breath sounds were tubular in character and there was increased vocal resonance. There were no accompaniments.

Over the remainder of the right lung and the

whole of the left lung the breath sounds were vesicular with a prolongation of expiration. There were no accompaniments.

Vocal resonance was normal.

Pharynx and larynx normal.

Circulatory System:

The apex beat could not be made out on palpation.

On percussion the superficial area of cardiac dulness was found to be obliterated.

On deep percussion the right side of the heart was found to be dilated, the right border being made out half an inch to the right of the sternum.

On auscultation the heart sounds were found closed in all areas.

Subsequent History:

This patient was obliged to cease work for three months, during which time his general health rapidly improved, he lost his cough and gained seven pounds in weight. He expressed himself to me as being "quite well" and acting on his feelings has returned to his occupation as a hewer but has obtained a more healthy area in which to work.

CASE III.

Illustrating effects produced by working in gunpowder laden atmosphere.

Alfred Eastham, coal-miner, aged 32 years. Seen 12th June, 1909.

Complaint:

Cough and shortness of breath.

Family History:

Mother died, aged 34, at child-birth. Father died, aged 50 years. Cause, heart-disease. Patient has one sister alive and in good health. He was unmarried.

Personal History:

Coal-miner since he was 13 years of age and a coal-hewer for 12 years. Always been a very hard worker. Moderate drinker and smoker. He used much gunpowder when at his work, an average amount per week for him being 15 lbs.

Previous Illnesses:

He had suffered from regularly recurring attacks of asthma. This he said did not trouble him until four years ago when he started using the gunpowder to excess. The attacks came on most frequently when he was working in a part of the mine where it was necessary to use much powder to get the coal out.

They lasted four or five days and when the "powder reek" got off his chest he felt comparatively well again though his shortness of breath and his cough never entirely left him.

Present Illness:

Patient finding that his asthmatic attacks were recurring at alarmingly short intervals began to grow alarmed lest he was taking consumption. When seen by me on June 12th, 1909, he was suffering from an acute attack of bronchial asthma. His temperature was 101°, and his pulse 110, and respirations, which were laboured, 25 per minute. He was sitting up in bed and many sibilant rhonchi could be heard on extra auscultation.

Questioned as to the cause of his attack, he said he attributed it to the excessive use of gunpowder as mentioned above. This produced the following symptoms.

A constant headache which affected the back of his head.

This was accompanied by a dryness of his throat; he sought relief from this by smoking his pipe and swallowing the saliva.

He suffered from palpitation of his heart and often felt that if he could vomit he would be better. At times the fumes from the powder would cause him to

feel sleepy and he had a marked loss of power in his arms and legs.

Physical Examination:

Patient was a man of moderate development. Height 5 feet 5 inches. Weight 9 stones 9 lbs.

Respiratory System:

Inspection:

Chest markedly barrel-shaped. Expansion poor and there was marked bulging of the apices on coughing. Measurement of chest at level of nipple on expiration 34", on inspiration 35".

Palpation:

Vocal Fremitus slightly diminished in all areas but there was a marked thrill communicated to the hand from the many rhonchi which were present.

Percussion:

The percussion note was hyper-resonant in all areas and the superficial area of cardiac dulness obscured.

Auscultation:

The breath sounds in all areas were harsh and vesicular, with a marked prolongation of expiration. There were innumerable rhonchi of all pitches present over the entire chest and the vocal resonance was normal.

Pharynx and Larynx:

There was marked congestion of the mucosa of both the pharynx and larynx.

Circulatory System:

The superficial cardiac dulness was obliterated as above. The apex beat was not palpable and the right chamber of the heart was somewhat dilated, being made out ¼" to the right of the sternum. The heart sounds were closed in all areas.

There was some pulsation in the veins of the neck.

This man was advised to give up coal-hewing for some time and work in an atmosphere of greater purity, which he did.

He was seen by me again on November 20th, 1909, and was found to be very much improved in his general health. He had had no recurrence of his asthmatic attacks. His chest condition was much better and on examination there was, with exception of one or two dry râles in the infrascapular and mid-axillary regions on the right side, and in the mid-axillary region on the left side, an absence of morbid accompaniments although there was naturally persistence of the emphysematous symptoms.

CASE IV.

Illustrating Fibroid-Phthisis.

George Marden, aged 27 years, coal-miner, married. Seen February 19th, 1909.

Complaint:

Cough and shortness of breath. Dryness of the throat and a black spit in the mornings.

Duration:

Six months.

Family History:

Good. Father alive and well, aged 60 years. Mother alive and in good health, aged 57 years. Originally, three brothers and two sisters; present number two brothers and one sister. Brother died as result of an accident and sister in infancy. Patient had three children alive, and healthy.

Personal History:

Environment: He had a good home and in good circumstances. He was a non-smoker and moderate drinker. He had worked at a mechanical coal-cutter for three years, up to the time of my seeing him. He attributed his illness to the fact that he had not safeguarded himself from the stone, coal and iron dust which was present in large quantities in the air where he worked. This he did for the first year by

wearing a respirator, but he thought he could do better work without it and he abandoned its use.

Previous Illnesses:

None of note. Influenza four years previously from which he made a good recovery.

Present Illness:

During the six months previous to his seeking advice, patient had noticed that he had first a cough in the mornings. This was of an irritating character and he would get relief after bringing up a small quantity of viscid, black phlegm.

He did not pay much heed to this at first as he was making a good wage and was unwilling to give up this kind of work.

These symptoms became gradually more marked and in addition he began to notice that he was becoming short of breath.

He found that it took him longer to go down the mine, to where he was working, than it formerly did, and when he was returning from his work he found that he had difficulty in ascending a drift of 300 steps which he had to traverse daily. He began to find also that he was unable to take his food as formerly; he used to take "Epsom salts" "to get the dust off his stomach" but without experiencing any real relief.

Finding his condition was getting no better, he sought advice and when seen by me on February 19th, 1909, his condition was as follows:

Physical Examination:

General Condition:

Patient was a man of moderate physique. Height 5 feet 7 inches, and weight 11 stones. He had a somewhat anxious expression. He thought he had lost weight but could not say how much. His temperature was normal and his pulse slightly increased, 76 per minute.

Respiratory System:

Respirations 18 per minute. Character, regular and abdomino-thoracic.

Inspection of chest:

Shape - markedly barrel-shaped. Expansion poor and this was most noticeable at both apices.

Measurements - Expiration 35", inspiration 36½".

Palpation:

Expansion found defective at both apices, the right more so than the left.

Vocal Fremitus was increased at both apices, back and front.

Percussion:

Right lung: An area of dulness was here made out extending to the level of the 1st rib anteriorly and to the level of the upper border of the scapula posteriorly. Over the remainder of the right lung the percussion note was slightly hyperresonant.

Left lung: On percussion an area of dulness was defined at the apex similar to that found in the right lung. Over the remainder of this lung the percussion note was normal.

Auscultation:

Right lung: Over the above mentioned area of dulness the breath sounds were vesicular but somewhat harsh in character, with prolongation of expiration. Over the remainder of the lung they were vesicular and somewhat distant in character. There were no accompaniments.

Left lung: The character of the breath sounds at the apex of this lung was similar to that of the right lung. There were a few medium pitched crepitations to be heard.

Over the remainder of this lung the breath sounds were vesicular and there were no accompaniments. The vocal resonance was increased at the apices of both lungs. Over the remainder of both lungs it was normal in character.

The sputum was greyish in colour and muco-purulent in character.

Pharynx and Larynx:

There was marked pharyngeal congestion and on laryngoscopic examination the vocal cords were found somewhat congested. They moved equally on respiration.

Circulatory System:

The heart was not enlarged. The superficial cardiac dulness was not observed and the sounds of the heart were closed in all areas.

The pulse was normal in character. Rate 76.

Subsequent History:

This man was advised to stop working among the dust laden air and to take an entire rest for a month. This he did and on returning to work at the end of that period, he was given employment in a well-ventilated part of the mine.

He was seen by me again on November 22nd, 1909 when he expressed himself as feeling very much improved in health. He was practically free from his cough, though he still had it slightly in the mornings. He would then bring up a little grey coloured sputum. His pharyngeal condition was much improved and he suffered from none of his previous throat dryness.

He had gained in weight altogether 7 pounds, his weight now being eleven and a half stones.

On examining his chest, the areas of dulness at both apices were still present and the physical signs similar to those discovered when he was first seen with the exception that there were now no accompaniments to be heard in either lung.

CASE V.

Illustrating Fibroid-Phthisis.

Robert Wren, aged 35 years. Electrician. Married. Seen May, 1909.

Complaint:

Feeling of tightness at chest. Shortness of breath, a black spit and a constant irritating cough.

Duration:

Two months.

Family History:

Good. Mother alive, aged 60 years. Father died, aged 50 years; cause, heart-disease. Two brothers alive and in good health. Patient had three children, all strong and healthy.

Personal History:

Patient was a man who had a good home and had always led a careful life. He was a tea-totaller and non-smoker. His illness he attributed to his employment which was as electrician driving a mechanical coal-cutter. He was thus exposed to an atmosphere thick with coal-dust and stone-dust.

Present Illness:

For three years patient had been employed to drive a mechanical coal-cutting machine. During the first year of this time he had worn a respirator to

prevent his inhaling the dust in the air. On this instrument becoming worn out he had made no application for a new one as he had suffered no ill-effects.

After he had been working without one for some months, he became aware that his employment was not agreeing with him. He was well paid, however, and being an experienced workman, he was persuaded to remain as long as he felt able. During the last two months that he was working his health was very indifferent.

He had a constant short irritating cough. This at first only troubled him when he got home from work for an hour or so, but gradually became more persistent until it was constantly with him.

He found, and on this point he was very emphatic, that his cough was invariably worse when the machine was working in a direction opposite to that of the air current in the working.

This he explained was due to the fact that when driving the machine, he sat behind it and thus all the dust was carried straight towards him.

This constant cough was after a time accompanied by a feeling of tightness at his chest. He was also getting short of breath.

He found that it was necessary for him to drink large quantities of cold tea in order to relieve a

constant feeling of dryness at the back of his throat.

The only medicine he had taken to relieve his symptoms was an occasional aperient.

Physical Examination:

General Condition:

Patient was a man of small stature; height 5 feet, and weight, 9 stones 7 lbs. He thought that he must have lost weight, though how much he was unable to state. He was a man of intelligent appearance.

Respiratory System:

Respirations, 18 per minute. Character, abdomino-thoracic, and regular in rate.

Inspection:

Shape - well formed and deep. No visible abnormalities.

Measurements - Expiration 34¼". Inspiration 37¼".

Expansion:

This was good except at the right apex which lagged somewhat behind the rest of his chest.

Palpation:

Expansion as described above.

Vocal Fremitus was found to be increased at both apices anteriorly and posteriorly. This increase

was most marked on the right side.

Over the remainder of both the right and left lungs the vocal fremitus was normal in character.

Percussion:

Right lung: The apex of this lung extended for a distance of 1½" above the level of the clavicle.

There was an area of dulness made out which extended from the apex to the level of the upper border of the scapula behind and to the upper border of the first rib in front. The percussion note over the remainder of this lung was healthy.

Left lung: The apex of this lung extended for a distance of 1½ inches above the level of the clavicle.

There was an area of dulness which was not so marked as on the right side. It faded into a normal lung note at the upper border of the scapula behind and at the level of the clavicle in front.

Auscultation:

Right lung: Over the area of dulness described above, the breath sounds were tubular in character both back and front. The vocal resonance was increased and there was a considerable number of crepitations to be heard.

Over the remainder of this lung the breath sounds were vesicular in character and the vocal resonance

normal. There were one or two dry râles to be heard at the base posteriorly.

Left lung: The breath sounds over the apex of this lung were harsh, vesicular in character, with some prolongation of expiration.

There were one or two crepitations to be heard and the vocal resonance was increased, though not to such an extent as on the right side.

Over the remainder of this lung the breath sounds were vesicular in character and the vocal resonance normal.

At the base of this lung, there were one or two dry râles.

The sputum was dark grey in colour and muco-purulent.

Pharynx and Larynx:

There was much pharyngeal congestion and the vocal cords were found on laryngoscopic examination to be congested.

Treatment and Subsequent History:

This man was advised to rest for a few weeks and to cease working underground for some months after that. He was given suitable employment at the end of two months.

He was seen by me again in November, 1909. He

expressed himself as feeling very much improved in his general health. His weight which had previously been 9 stones 7 lbs. was now 11 stones and he had an excellent appetite. He was still somewhat short of breath but this he attributed to his being much stouter.

On examining his lungs, the condition of his right apex was unaltered, excepting that there were now no accompaniments to be heard.

His left lung showed an area of comparative dulness which was, if anything, more marked than it was when he first came under observation.

There were no accompaniments to be heard.

He had now very little cough and no dryness of his throat which had previously caused him much distress.

His pharynx and larynx were healthy.

CASE VI.

Illustrating effects produced by working in carbon dioxide.

Thomas Burn, aged 64 years. Coal-hewer. Seen 30th November, 1909.

Complaint:

Shortness of breath.

Duration:

Patient was unable to say definitely how long he had been suffering, but his symptoms had been much more distressing during the two months previous to his seeking advice.

Family History:

Patient had one son and five daughters alive and in good health.

Personal History:

Patient had a good home. He was a fairly heavy drinker, but only at the end of the week. He took none at other times and lost no work through it.

He was a non-smoker and had worked down the pit for 55 years, having started at the age of nine. He used an average of 5 lbs. of gunpowder per week.

Previous Illnesses:

None of note. Patient could not remember ever having suffered from any previous chest ailment.

Present Illness:

For some years patient had been somewhat short of breath. He paid very little heed to this, thinking it was natural at his years. He had, however, suffered much from this symptom during the two months previous to my seeing him. This he attributed to the fact that he was working in a very poorly ventilated part of the mine. This had been so bad at times that he had had to work in the dark as his candle would not burn at all. There was much stythe ($C O_2$) present , and at times he had to go out of the working and get into the fresh air or he would have been overcome with it. He knew when he could stand it no longer as then his limbs seemed to lose their power.

He would stand and gasp for air without experiencing any relief.

During this time he had suffered much from a frontal headache and palpitation. This last symptom was so bad that at times he could hear his heart beating. He suffered from vague stitching pains in his chest.

His condition was at times so distressing that he had put his finger down his throat to try and make himself vomit in the hope that his symptoms would be relieved. He had a constant dryness of his throat, and cough. This last he had had more or less for

years, but it had latterly been very troublesome.

He had a black spit when he returned from work.

Physical Examination:

General Condition:

Patient was a big, powerful man, well developed and well-nourished. He had an anxious expression, and looked somewhat cyanosed and breathless. His temperature was 99°, pulse 84, and respirations 22. His height was 5 feet 7½ inches, and his weight 12 stones.

Respiratory System:

Inspection of chest:

Shape - asymetrical. There was marked bulging over the praecordial region. This patient said had been there ever since he could remember. There was some drooping of the right shoulder.

Expansion:

The expansion of the chest as a whole was fairly good. It was deficient at the apex of the right lung, and over the base of the left lung there was marked indrawing of the intercostal spaces on inspiration. This was most marked over the 7th, 8th and 9th interspaces in the infra-axillary region.

Measurements - Expiration 38", right lung 20"

Inspiration 40", left lung 19".

Palpation:

This confirmed what had been noted on inspection as to the expansion of the chest.

Vocal Fremitus:

This was increased at the right apex back and front. Over the remainder of the right lung it was not very marked.

Over the left lung the vocal fremitus was normal except at the base and infra-axillary region where it was somewhat faint in character.

Percussion:

Right lung: The apex of the lung was found to extend for a distance of 2½" above the clavicle.

There was an area of dulness here which extended in front to the level of the 2nd rib and behind as far as the spine of the scapula.

The percussion note over the remainder of this lung was somewhat hyperresonant in character.

Left lung: The apex extended for a distance of 2½" above the clavicle. The percussion note was normal except over the base posteriorly and in the infra-axillary region where the percussion note was dull in character.

Auscultation:

Right lung: The breath sounds over the area of

dulness above mentioned were harsh in character and there was prolongation of expiration. Over the remainder of the lung the breath sounds were vesicular with prolongation of expiration.

The Vocal Resonance was increased over the right apex and diminished at the base of the left lung and in the left infra-axillary region. There were numerous dry râles to be heard over both lungs.

Sputum:

Copious and dark grey in character.

Pharynx and Larynx somewhat congested.

Circulatory System:

The apex beat was not palpable.

The right side of the heart was slightly dilated, and the apex beat was situated in the sixth interspace.

The sounds of the heart were closed in all areas.

Subsequent History:

This man was ordered away for a prolonged change of air, after which he commenced shift work, that is, work where the mine is well ventilated. He is now much improved in health.